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THE DEMAND FOR FERTILIZER IN SOUTHERN BRAZIL,

1948 - 1971

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The Demand For Fertilizer In Southern Brazil, 1948-71

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Introduction

The physical relationship between chemical fertilizer use and crop yields has been widely documented. From these studies, specialists have prescribed the level or amount of fertilizer which farmers should use. Very little work, however, has been done on the economic factors associated with the farmer's actual use of fertilizers in developing countries.1/ Nevertheless, it is well known that increased agricultural production and modernization have been associated with substantial increases in purchased farm inputs: fertilizer, machinery, seed and others.

The secular decline of world fertilizer prices in relation to farm product prices has stimulated increased fertilizer use and agricultural production in most developed and developing countries of the world. It is, however, very evident that these price relationships have changed abruptly in the last year. The world-wide food shortages and consequent higher food prices combined with the current energy crisis with its fertilizer shortages and significantly higher prices have created entirely new fertilizer-farm product price relationships. Thus, it becomes highly relevant to determine the impact which these new prices will have on fertilizer use and food production in developing countries. This paper investigates the economic factors which affect the use of fertilizer in Sao Paulo, Brazil, an area which has already experienced dramatic changes

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in fertilizer-product price relationships similar to those occurring more generally around the world today. The general hypothesis tested is that the substantial increase in the use of fertilizer has occurred primarily in response to a fall in the price of fertilizer relative to prices for crops. An aggregate demand function for fertilizer is defined and estimated to investigate whether it can explain most of the variation in fertilizer use.

Fertilizer in Brazil

The Brazilian government has used credit and price policies to accelerate the adoption of new technology[2/]. The policy instruments used to stimulate fertilizer consumption included preferential import exchange rates, expanded supplies of credit at concessional interest rates for the purchase of modern inputs including fertilizer, loans and loan guarantees for new fertilizer production facilities, and guaranteed minimum support prices for most food crops.

Fertilizer use in Brazil, stimulated by these policies, has increased rapidly in the last 20 years. Brazilian fertilizer use increased from 88.5 thousand tons of N, P_2O_5, K_2O in 1950 to 1,126.0 thousand tons in 1971, a compound annual growth rate of 16.0 percent. From 1961 to 1966, a period of great political and economic instability, use increased at a compound annual rate of 1.0 percent. Since 1967, fertilizer utilization has increased at a compound annual rate of 34.0 percent. Use of macronutrients (N, P_2O_5, K_2O) per cultivated hectare increased from 5 kg/ha in 1950 to 8.5 kg/ha in 1964; in 1970 consumption was 27.0 kg/ha.

Fertilizer use in Brazil, however, is still much less than for many countries of the world (See Table 1). Application in the developed and developing countries is much higher than in Brazil. Use in Sao Paulo, on the other hand, nearly equals use levels in the U.S. and Italy; and exceeds

TABLE 1: Fertilizer Use Per Arable Hectare in Brazil and Various Countries, 1970-71

Country	N	P_2O_5	K_2O	Total
		Kg/ha		
Brazil	8.0	12.2	9.0	29.2
Sao Paulo	22.7	27.1	23.0	72.8
Spain	26.2	20.8	10.0	57.0
Italy	39.8	34.7	15.1	89.6
Yugoslavia	36.6	22.7	19.4	78.7
Israel	75.6	34.3	25.7	135.6
New Zealand	10.3	414.9	154.3	579.5
Russia	19.8	9.5	11.1	40.4
Taiwan	177.6	49.0	69.3	295.9
France	75.4	93.9	72.1	241.4
Holland	467.4	126.2	155.7	749.3
Chile	9.3	22.0	3.1	34.4
India	9.0	2.8	1.4	13.2
U.S.A.	40.7	24.6	21.5	86.8

Source: "Annual Fertilizer Review" FAO 1971, Brazil and Sao Paulo data are taken from Brazilian Agricultural Sector by Ruy Miller Paiva, Salomao Schattan and Claus F. Trench de Freitas. Secretary of Agriculture. Sao Paulo 1973.

fertilizer use per hectare in Russia.

Crop productivity is also low relative to the United States and world averages (See Table 2). Brazilian yields of corn, cotton, rice and soybeans are less than the world average and substantially less than the U.S. average. Sao Paulo yields for the same crops are higher than those for Brazil and almost equal or even exceed the world averages; they are, however, much less than U.S. yields for all crops except soybeans.

Three possible explanations of the low fertilizer use and productivity levels are: 1) low yields from fertilizer use, 2) unfavorable price relationships and 3) farmers are only part way into the adoption process.

The first alternative was analyzed in a recent paper by Nelson and Meyer (13), and has important implications for this study. Their conclusions are that: 1) adoption rates in the region studied are quite high, 2) actual farm use is much less than the use levels recommended by the extension service, 3) the value of marginal product of fertilizer was low and even negative, for some nutrients on some crops and 4) optimal levels of fertilizer use are therefore low.

This low yield response from fertilization suggests a flat or low profile production surface and implies a relatively elastic demand function for fertilizer. If the demand function for fertilizer is elastic, farmers will be highly sensitive to changing fertilizer prices. The decline in fertilizer prices observed during the last 20 years should, therefore, be an important factor in explaining increased fertilizer consumption.

<u>Area Studied</u>

The state of Sao Paulo was chosen for this study because it is the most highly developed in Brazil and accounts for 60 to 65 percent of the national fertilizer use. It also has a highly diversified agriculture which produces many annual and perennial crops as well as livestock and

TABLE 2: Average Yields of Various Crops in Brazil, Sao Paulo, United States and World, 1969-70

Crops	Brazil	Sao Paulo	United States	World
		kg/ha		
Corn	1470	1910	4500	2410
Cotton	690	1079	1350	1010
Rice	1640	1225	5120	2260
Soybeans	1250	1462	1800	1330

Source: FAO Production Yearbook - 1970, Vol. 24, Rome 1971. Instituto de Economia Agricola Desenvolvimento da Agricultura Paulista Secretaria da Agricultura, Sao Paulo, March, 1971.

livestock products. Production technology for many crops is modern and employs large amounts of modern inputs. In addition, the time series data for the years 1948-71, the period of this study, were readily available for the State of Sao Paulo.

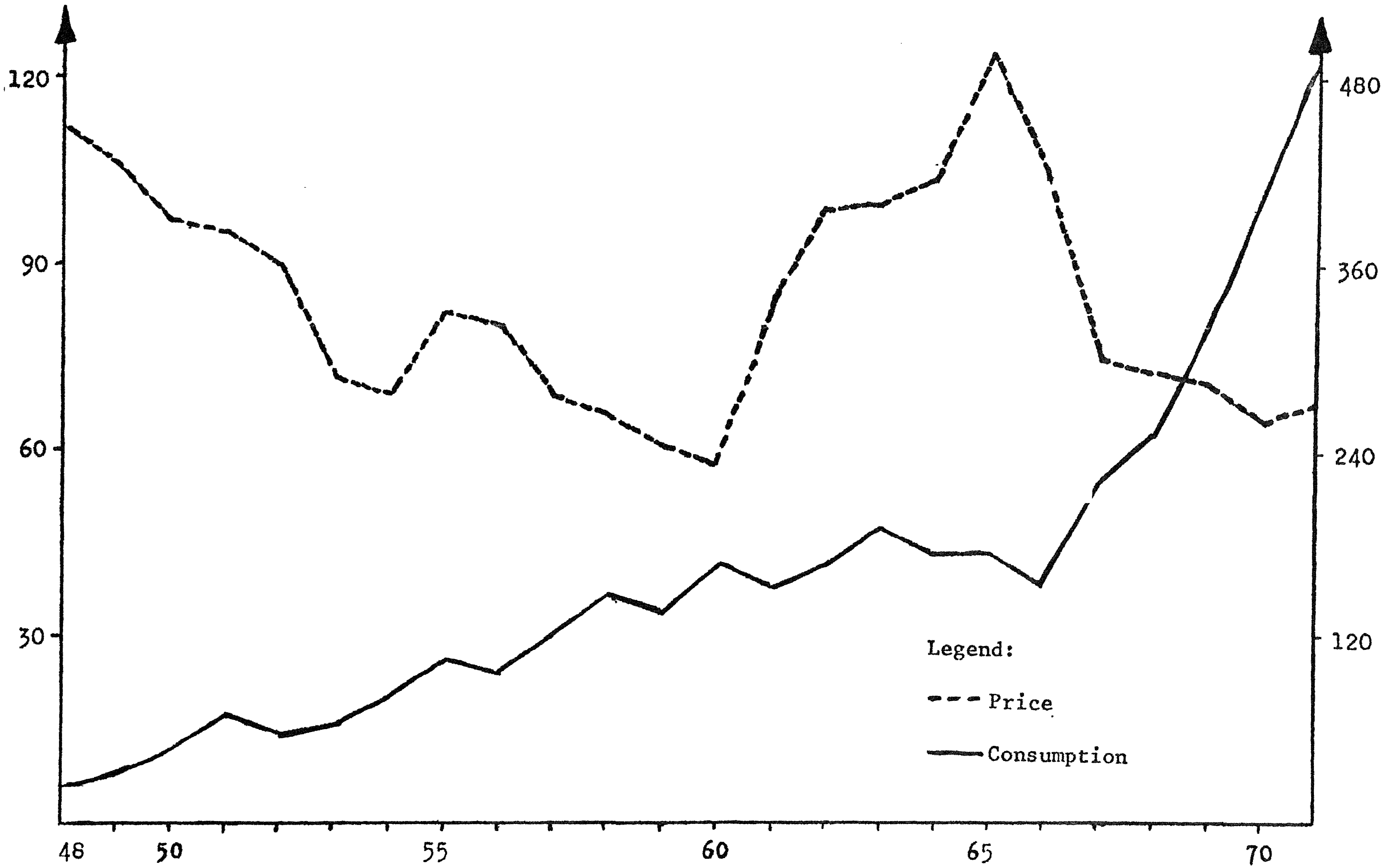
Use of fertilizer in Sao Paulo increased from 24,000 metric tons of (N, P_2O_5, K_2O) in 1948 to 491,000 metric tons in 1971, which is 20 times more than that consumed in 1948. Total use increased at an average annual rate of 13.4 percent in this same period. Application per hectare of cultivated land in Sao Paulo was 86 kg/ha in 1971, or 14 times the 6 kg/ha used in 1948; use per hectare has tripled in the last ten years. This intensification in the use of fertilizers occurred at the same time that area cultivated increased 29 percent.

Fertilizer consumption increased steadily from 1948 to 1971. There were some years, however, when it actually declined (See figure 1). Use increased steadily at an average annual rate of 19.3 percent from 1948 to 1960. A downward trend in use actually occurred at an average annual rate of -1.2 percent from 1961 to 1966, the years during which Brazil suffered a very high rate of inflation. In the 1967-71 period, fertilizer use rebounded, increasing at an average annual rate of 26.4 percent.

This tremendous growth in fertilizer use occurred at a time when Sao Paulo fertilizer prices, consistent with world-wide trends, were declining; the index of deflated prices for fertilizers decreased substantially from 100 in the base period 1948-52, to 68 in 1971 or 32 percent. The price index declined steadily until 1960 and then increased sharply reaching a new high in 1965. Since 1965, fertilizer prices have once again declined steadily through 1970. (See figure 1).

The index of deflated prices for agricultural crops also declined during this same time period. The decrease, however, was less than observed for fertilizer prices. The index of deflated crop prices declined

Figure 1 - Index of real prices of Fertilizers and Fertilizer Use in the State of Sao Paulo for the period 1948-71.



Note: Index deflated by National Index "2" of the "Conjuntura Economica" Getulio Vargas Foundation (base: 1948-52 = 100) and, consumption in 1,000 tons of macronutrients (N, P_2O_5, K_2O)

16 percent from the 1948-52 base period to 1971, which is one-half of the decrease observed for fertilizer prices. The price of fertilizers in relation to crop prices has therefore decreased in the studied period thereby contributing to increased fertilizer use.

Besides these developments, many other changes took place during the studied period which are not discussed in this paper. The most important of these are the credit programs initiated to 1966 to subsidize the purchase of modern inputs such as fertilizers at negative real rates of interest[3/].

Other factors, such as the increased availability of technical information about fertilizer use and improved marketing techniques have also contributed to the rapid increase in fertilizer use observed in recent years.

The Models

A traditional demand model and the Nerlove adjustment model were selected for this study[4/]. The demand function used considers fertilizer to be a function of the relevant product and input prices, area cultivated, crop yields and time.

The functional forms chosen for the estimation of the demand function are an equation linear in the logarithms of the variables and a linear equation; the latter is not included here because of its generally poorer fit.

A. Traditional Model

1. $$Y_t = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3(t-1)} + a_4X_{4(t-1)} + a_5X_{5t} + e_t$$

Where Y = total consumption of N, P_2O_5, K_2O in kilograms

X_1 = index of deflated prices of fertilizers

X_2 = index of area cultivated in hectares

X_3 = index of crop yields lagged one year

X_4 = index of deflated crop prices lagged one year

X_5 = time in years

e = error term

The fertilizer and crop price variables in these demand functions have traditionally been handled in essentially two ways. The first and most common method is a current or expected price ratio similar to that used by Griliches (4,5). A second method used by Heady and Yeh (6) specifies separate variables for fertilizer and crop prices. We adopted the latter approach in this study because it seemed more appropriate in the Brazilian situation.

Area cultivated was included to determine its importance in explaining fertilizer use. The index of crop yields lagged one year is similar to that of lagged rice yields in Hsu's study in Taiwan and to cash income from farming lagged one year in Heady and Yeh's demand function for fertilizer (7,6).

The time variable represents the farmers' increasing familiarity with and willingness to use chemical fertilizers.

Adjustment Model

(2) $Y^*_t = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3(t-1)} + a_4X_{4\,(t-1)} + e_t$

(3) $Y_t - Y_{t-1} = b\,(Y^*_t - Y_{t-1}) \quad o<b<1$

where Y^* = desired or long run equilibrium level of fertilizer use; a_i = long run coefficient of demand for fertilizer (or elasticity of demand if the variables are in logarithms); and b= adjustment coefficient.

This is a Nerlove adjustment model, used by Griliches and others (1, 4,5,7). It assumes that the long run equilibrium demand for fertilizers is a function of the specified variables and that the change in fertilizer use between periods takes place in proportion "b" to the dis-equilibrium ($Y^*_t - Y_{t-1}$).

Substituting equation 2 in 3 and solving for Y_t, one obtains:

(4) $Y_t = a_o\,b + a_1b\,X_{1t} + a_2\,b\,X_{2t} + a_3bX_{3(t-1)} + a_4bX_{4(t-1)} + (1-b)\,Y_{t-1} + b\,e_t$

This is the equation estimated in the following sections for the period

1948-1971, and for two sub-periods 1948-1960 and 1966-1971. The sub-period estimations were made because the total period included the years 1961-1965 when inflation in Brazil reached its highest levels adversely affecting the price relationships in many sectors of the economy including agriculture. It was a period of great political and economic instability.

The Data and The Variables

The basic data used in this study were obtained from the Institute of Agricultural Economics of the Secretary of Agriculture of the State of Sao Paulo, an agency which collects, processes and publishes economic information for the agricultural sector of Sao Paulo. All variables expressed as indices have as their base period 1948-52 = 100.

Fertilizer consumption for the State of Sao Paulo is measured in thousands of tons of the three basic macronutrients (N, P_2O_5, K_2O). Since data on carry-over stocks from year to year are not available, this actually refers to apparent total use.

The fertilizer price index refers to average sales price to farmers of the principal fertilizers in the city of Sao Paulo weighted annually by the relationship among the three macronutrients (N, P_2O_5, K_2O).

The area cultivated index is calculated from the hectares planted to the 17 main crops of Sao Paulo which account for almost all fertilizer consumption. The products included are cotton, potatoes, sugar cane, silkworm, oranges, soybeans, tomatoes, peanuts, coffee, tea, banana, onions, manioc, corn, rice, beans and castor beans.

The index of crop yields for these same 17 crops is obtained from the annual physical yield data using a Paasche index with a weighted moving average of the area cultivated.

The crop prices index for these 17 products represents average annual prices received by farmers for crop products in the State using the Laspeyres method weighted by the average production in the five-year period 1956-60

Regression Results

The regression results for the models of each period are given in Tables 3, 4 and 5 respectively[5/]. The best results in terms of statistical significance, expected signs and stability of values are produced from distributed lag model.

For the period 1949-71, the signs of the price variable are consistent in the traditional model, and the coefficients are statistically significant; however, their value changes considerably as other variables are included in the regression (See Table 3). Price and area cultivated are statistically significant at the 5% level in equation II, although the addition of the time trend (equation III) removes all significance from the area cultivated variable and also affects the price variable. The addition of the yield variable and the price received variable did not improve the results of the traditional model. The time trend is the single most important variable in all of these equations; these results parallel those of Knight for Rio Grande do Sul and Hsu for Taiwan (7,9).

Another problem of equation I-III of the traditional model is the low value of "d", the Durbin-Watson statistic, indicating the existence of serial correlation in the residuals.

The adjustment model provides the best overall results for the 1949-71 period; equation IV containing the price variable and the lagged dependent variable is superior to all others tested. The price variable is significant at the 20 percent level and has the expected sign. Its value remains highly stable in all these equations. The lagged dependent variable is significant at the 5 percent level. None of the other equations which include one or more of the variables-area cultivated, crop yields or prices

Table 3 - Regressions Results: Demand for Fertilizers in the State of Sao Paulo 1949-71.

	Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2	D-W
Traditional Model (in Logs)									
I	4,305	-1.136** (1.68)	-	-	-	-	-	0.120	0.14
II...............	9,169	-1,119**** (2.90)	6.518**** (6.64)	-	-	-	-	0.726	0.84
III..............	0,014	-0.400** (1.43)	1.099 (0.93)	-	-	0.658**** (5.44)	-	0.893	0.51
Adjustment Model (in Logs)									
IV...............	0,732	-0.248** (1.35)	-	-	-	-	0.903**** (16.99)	0.943	2.04
V	0,531	-0.322 (1.60)	0.753 (0.94)	-	--	-	0.834**** (8.75)	0.942	-
VI...............	0,351	-0.242* (1.30)	-	0.203 (0.68)	-	-	0.883**** (14.44)	0.944	2.19
VII..............	1,116	-0.240* (1.29)	-	-	0.177 (0.69)	-	0.878**** (13.52)	0.944	2.20

Note: Dependent Variable: Y=Apparent consumption of fertilizers in terms of macronutrients (N-P-K); X_1 = real average price of fertilizers; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by Sao Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1} = the same as Y lagged one year.

Significance levels: **** to 5% or less; *** to 10%; ** to 20%; and * to 30%.

received-provide better results; their coefficients are not significant, the R^2 does not improve and the price variable is significant only at the 30 percent level.

In the adjustment model equations, the value of "d" indicates the absence of serial correlation in the residuals.

The short run price elasticity of equation IV equals -0.248, the adjustment coefficient "b" equals 0.10 and the long run price elasticity equals -2.48. An adjustment coefficient of 0.10 indicates that approximately 10 percent of the difference between actual and desired consumption is completed within one year. The adjustment coefficient in equations IV-VII averages 0.12, which is about half the value that Griliches found for the U.S. The short run elasticities which average -0.25 are half of the -0.5 for the Griliches study, however, the long run elasticities are approximately equal (4).

The regression results for the first sub-period 1949-1960, are shown in Table 4 for the traditional and adjustment models. They are quite similar to those of Table 3 because the results of the traditional model are less satisfactory than those of the adjustment model. The fertilizer price variable and the area cultivated variable are statistically significant at the 5 percent and 20 percent levels, respectively (Equation II). The coefficient of the price variable equal to -1.68 indicates an elastic demand for fertilizer. Introduction of the time trend in equation III causes both the fertilizer price and the area cultivated variables to lose their statistical significance. This is caused by the high partial correlation coefficient among the variables, area cultivated and time.

The yield and prices received variables had no statistical significance in the equations tested for this period; even the sign of these variables was inconsistent.

The results of the adjustment model for this sub-period are somewhat

Table 4. - Regression Results: Demand for Fertilizers in the State of São Paulo 1949-60

	Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2
Traditional Model (in logs)								
I................	6,106	-2,210****	-	-	-	-	-	0,762
		(5,64)						
II	0,663	-1,677****	2,175**	-	-	-	-	0,802
		(3,09)	(1,36)					
III.............	0,437	-0,070	0,587	-	-	0,586****	-	0,922
		(0,12)	(0,50)			(3,50)		
Adjustment Model (in logs)								
IV..............	1,879	-0,608*	-	-	-	-	0,646****	0,906
		(1,21)					(3,73)	
V................	1,23	-0,391	1,365*	-	-	-	0,601****	0,923
		(0,75)	(1,25)				(3,49)	
VI..............	2,553	-0,701*	-	0,227	-	-	0,621****	0,908
		(1,24)		(0,43)			(3,26)	
VII.............	0,173	-0,758*	-	-	0,252	-	0,610****	0,910
		(1,30)			(0,56)		(3,21)	

Note: Dependent Variable: Y= Apparent consumption of fertilizers in terms of macronutrients (N-P-K); X_1= Real average price of fertilizers ; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by São Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1}=the same as Y lagged one year.

Significance levels: **** to 5% or less
*** to 10%
** to 20%
* to 30%

less satisfactory than those for the entire period, because the price variable is only significant at the 30 percent level in two equations and is insignificant in the third. Nevertheless, the sign of the price coefficient continues to be consistent, and the value of the price elasticity is stable. The short run price elasticity ranges from -0.61 to -0.76 which is much higher than for the entire period. Likewise, the adjustment coefficient "b" is also higher ranging from 0.35 to 0.39. The long run price elasticity ranges from -1.74 in equation IV to -1.95 in equation VI. Thus, results for this sub-period indicate less inelastic short run and less elastic long run demand elasticity than that estimated for the entire period.

Results from the 1966-71 sub-period (Table 5) are generally better than for the entire period 1949-71, or the sub-period 1949-60 for the traditional model as well as the adjustment model.

The coefficient of the price variable is significant at the 5 percent level in equations I and II and indicates a price elasticity of demand in the range of -2.38 to -2.86, much higher than that observed for the other periods.

Introduction of the time trend, however, causes a reduction in the price coefficient to -0.41, significant at the 30 percent level.

The adjustment model has price coefficients significant at the 5 percent level with short run price elasticities ranging from -1.60 to -1.69; and long-run price elasticities ranging from -4.48 to -5.28. The adjustment coefficient "b" for this period varies from 0.32 to 0.37; these values are about the same as those for the 1949-60 sub-period. None of the other variables tested such as area cultivated, crop yields, or crop prices was significant in this model. Thus the demand for fertilizer in this sub-period is considerably more price elastic in the short run and long run than that observed for the 1949-71 period or the 1949-60 sub-period.

Table 5. - Regressions Results: Demand for Fertilizers in the State of São Paulo 1966-71.

	Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2
Traditional Model (in logs)								
....	7,814	-2,865**** (4,07)	-	-	-	-	-	0,806
II..............	10,399	-2,379**** (3,45)	2,838** (1,51)	-	-	-	-	0,890
III.............	2,18	-0,41* (1,62)	-	-	-	4,11**** (11,28)	-	0,990
Adjustment Model (in logs)								
IV..............	3,849	-1,599**** (4,92)	-	-	-	-	0,671**** (5,68)	0,984
V...............	3,062	-1,613**** (4,19)	0,444 (0,40)	-	-	-	0,634**** (3,52)	0,981
VI..............	3,261	-1,694**** (3,97)	-	0,359 (0,47)	-	-	0,676**** (4,92)	0,985
VII.............	0,362	-1,660**** (4,19)	-	-	0,244 (0,48)	-	0,626**** (3,80)	0,985

Note: Dependent Variable : Y= Apparent consumption of fertilizers in terms of macronutrients (N-P-K); X_1 = real average price of fertilizers; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by São Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1}=the same as Y lagged one year.

Significance levels : **** to 5% or less
*** to 10%
** to 20%
* to 30%

Conclusions and Implications

We have seen from the above results of the adjustment model that price is important in explaining the demand for fertilizer and that Paulista farmers are responsive to changes in the prices of their inputs. None of the other variables tested -- crop prices received, crop yields or area cultivated -- were statistically significant. The distributed lag model provided a better fit of the demand function for fertilizer in the State of Sao Paulo than did the traditional model.

The price elasticity of demand for fertilizers is inelastic in the short-run and elastic in the long-run, -0.25 and -2.50, respectively, for the entire period. It appears, however, as though the demand for fertilizers has changed structurally between the 1949-60 sub-period and the 1966-70 sub-period as a result of greater political and economic stability in Brazil and of Government policies specifically designed to increase the use of modern inputs. The short-run price elasticity increased from about -0.68 in the first sub-period to -1.64 in the latter, and the long-run price elasticity increased from -1.84 to -4.87, respectively. Thus, demand for fertilizer has become more price elastic in recent years; in other words, for any given percentage increase in the price of fertilizer farmers will make a more than proportional reduction in the quantity used, other things unchanged. This conclusion, however, must be interpreted carefully because of the limited number of observations in the second sub-period. In addition, the co-efficient of the price variable could be biased owing to data limitations which did not permit inclusion of a credit variable. Additional research a few years hence will be able to measure this influence of credit.

These results, which indicate a long-run price elastic demand function for fertilizer imply that farmers are sensitive to fertilizer prices and that any change in these prices would lead to significant changes in quantity demanded. In sum, the downward trend in fertilizer prices observed in the last 20 years has been an important stimulant for greater use of modern inputs and increased agricultural production. These same factors may not be a stimulant in the future because fertilizer prices have increased very abruptly and may remain at these higher levels for many years.

A doubling of the price of fertilizer such as has occurred recently in world markets could therefore lead to large reductions in fertilizer use in the long-run. The exact impact of these new prices on fertilizer use and agricultural production will have to be watched very carefully.

In addition, the limited yield response from fertilizer use suggests that current production technologies may be exhausted and that more agronomic research will be necessary to achieve further productivity gains which increase the profitability of fertilizer use.

Policy makers will therefore have to observe very carefully the impact of these recent developments on their agriculture. More subsidized credit and even subsidized fertilizer prices might be required to maintain fertilizer use and agricultural production at recent levels.

- FOOTNOTES -

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1. The few studies about fertilizer consumption in the United States include Griliches (4,5) and Heady and Yeh (6). Studies of fertilizer consumption in developing countries include Parikh (15) Leonard (11) and Hsu (7). In Brazil there are several published studies which analyze the economic use ot fertilizer on different crops, such as the work of Nelson and Meyer (13), Lanzer (10), Wright (17), and Knight (9). But among all these studies only Knight tried to adjust a demand function for fertilizer in Rio Grande do Sul.
2. A more detailed discussion of the impact ot these policies on farm capital formation and modernization is available in Rask, Meyer and Peres (16).
3. Cibantos contains a thorough discussion of the policies and programs specifically designed to increase fertilizer use.
4. The demand functions were estimated directly from time series data by using the ordinary least squares method. Fertilizer prices in Brazil are generally considered to be "administered" with disequilibrium being expressed largely in seller's inventories. Thus, in the short-run price may be assumed to be predetermined.
5. Not all the equations adjusted and variables tested are included here because of space limitations.

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